

CLAIMS

1. A homogeneous process for the hydrogenation of dicarboxylic acids and/or anhydrides in the presence of a catalyst comprising:
 - (a) ruthenium, rhodium, iron, osmium or palladium; and
 - (b) an organic phosphine;wherein the hydrogenation is carried out in the presence of at least about 1% by weight water and wherein the reaction is carried out at a pressure of from about 500 psig to about 2000 psig and a temperature of from about 200°C to about 300°C such that from about 1 mol to about 10 mol of hydrogen are used to strip 1 mole of product from the reactor.
2. A process according to Claim 1 wherein the process is a continuous process comprising the steps of:
 - (a) feeding the dicarboxylic acid and/or anhydride to the hydrogenation reactor;
 - (b) hydrogenating the dicarboxylic acid and/or anhydride;
 - (c) recovering the product in an hydrogen stream;
 - (d) separating the product from the hydrogen stream;
 - (e) recycling the hydrogen stream to the reactor;
 - (f) separating any removed catalyst and recycling the catalyst to the reactor; and
 - (g) recovering the product.
3. A process according to Claim 1 or 2 wherein the dicarboxylic acid and/or anhydride is a C₄ dicarboxylic acid or anhydride such that the process is a process for the production of butanediol, tetrahydrofuran and/or γ -butyrolactone.

4. A process according to Claim 3 wherein any γ -butyrolactone produced in the hydrogenation reaction is recycled to the hydrogenation reactor.
5. A process according to Claim 3 or 4 wherein the C₄ dicarboxylic acid or anhydride is fumaric acid, maleic anhydride, maleic acid, succinic acid or succinic anhydride.
6. A process according to any one of Claims 1 to 5 wherein the water is present as the solvent for the reaction.
7. A process according to any one of Claims 1 to 5 wherein one or both of the reactants or the product are the solvent for the catalyst.
8. A process according to Claim 7 wherein a solvent is used and the water is present as an additive in the solvent.
9. A process according to any one of Claims 1 to 5 wherein the water is produced in situ as a by-product of the hydrogenation reaction.
10. A process according to any one of Claims 1 to 9 wherein the reaction takes place in more than one reactor and the reactors are operated in series.
11. A process according to any one of Claims 1 to 9 wherein the reaction is carried out at a pressure of about 900 psig.
12. A process according to any one of Claims 1 to 10 wherein the reaction is carried out at a temperature of about 240°C to about 250°C.
13. A process according to any one of Claims 1 to 12 the catalyst is a ruthenium/phosphine catalyst.

14. A process according to any one of Claims 1 to 13 wherein, the ruthenium is present in an amount of from 0.0001 to 5 mol as ruthenium per liter of reaction solution.
15. A process according to any one of Claims 1 to 14 wherein the phosphine is tridentate phosphine.
16. A process according to any one of Claims 1 to 14 wherein the phosphine is selected from trialkylphosphines, dialkylphosphines, monoalkylphosphines, triarylphosphines, diarylphosphine, monoarylphosphines, diarylmonoalkyl phosphines and dialkylmonoaryl phosphines.
17. A process according to Claim 16 wherein the phosphine is selected from tris-1,1,1-(diphenylphosphinomethyl)methane, tris-1,1,1-(diphenylphosphinomethyl)-ethane, tris-1,1,1-(diphenylphosphinomethyl)propane, tris-1,1,1-(diphenylphosphinomethyl)butane, tris-1,1,1-(diphenylphosphinomethyl)2,2dimethylpropane, tris-1,3,5-(diphenylphosphino-methyl)cyclohexane, tris-1,1,1-(dicyclohexylphosphinomethyl)ethane, tris-1,1,1-(dimethylphosphinomethyl)ethane, tris-1,1,1-(diethylphosphinomethyl)ethane, 1,5,9-triethyl-1,5,9-triphosphacyclododecane, 1,5,9-triphenyl-1,5,9-triphosphacyclododecane, bis(2-diphenylphosphinoethyl)phenylphosphine, bis-1,2-(diphenyl phosphino)ethane, bis-1,3-(diphenyl phosphino)propane, bis-1,4-(diphenyl phosphino)butane, bis-1,2-(dimethyl phosphino)ethane, bis-1,3-(diethyl phosphino)propane, bis-1,4-(dicyclohexyl phosphino)butane, tricyclohexylphosphine, trioctyl phosphine, trimethyl phosphine, tripyridyl phosphine, triphenylphosphine.

18. A process according to Claim 16 wherein the phosphine is selected from tris-1,1,1-(diarylphosphinomethyl)alkane and tris-1,1,1-(dialkylphosphinomethyl)alkane.
19. A process according to any one of Claims 1 to 18 wherein, the phosphine is present in an amount of from 0.0001 to 5 mol as phosphine per liter of reaction solution.
20. A process according to any one of Claims 1 to 19 wherein the catalyst is regenerated in the presence of water and hydrogen.